INDUSTRIAL RESEARCH & DEVELOPMENT

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Small companies are the most inventive

Microscope lens system controls reflectivity

Microprocessor, micro-computer, microscope

News of importance to people who work in R&D

Sharp photos made from poorly reflective crystals, see page 106.

INDUSTRIAL RESEARCH & DEVELOPMENT

SERVING THE $142.5-BILLION WORLD-WIDE R&D INDUSTRY

EDITORIAL

11 **We have nothing to lose but the chains**

DEPARTMENTS

19 **Innovative notebook**
25 **Product development**
31 **A lawyer's view**
39 **Research trendletter**
45 **R/D News in brief**
147 **Vacuum technology**
157 **Island for science**
163 **Special new products**
167 **New products**
181 **Literature**
193 **Bookshelf**
194 **Opinion poll questionnaire**
197 **Letters**
200 **Advertisers' index**
203 **Reader service card**

ABOUT THE COVER

For materials of low reflectivity, microscopy often is difficult. Unless special precautions are taken, indistinct or blurred images may result.

Most nonmetallics, including coal, plastics, and other organics fall into this category. In addition, it often is difficult to distinguish similar alloys under ordinary illumination.

The cover photo depicts a mixture of two aluminum alloys using an 8 by 10-in. instant camera attachment on a Zeiss Axiomat-Nomarski differential interference contrast Planachromat at 250X.

Shown above is an 80X photo of a mixture of strongly birefringent crystals (olivine) made in the same way. A related article begins on p. 106.

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NEWS OF SCIENCE AND TECHNOLOGY

53 **Environment:** Fluorocarbons may not harm Earth's ozone layer after all; testing begins on PV solar cells; computer-graphics system for solids design

55 **Space:** *Columbia* completes a successful mission, but commercial future of the shuttle is still distant; U.S.-Russian cooperative space efforts yield results; carbon-fiber reinforced rudder is tested

64 **Astronomy:** Mineral formation in meteorites raises questions about how the solar system cooled; evidence supports superluminal expansion; astronomers make ground-based submillimeter observations

72 **Oceanography:** Device uses space technology to explore ocean floor

76 **Technology:** GAO blasts Commerce Dept. on exporting technology; European satellite tracking station takes shape

80 **Biology:** Heavy ion microscopy promises new insights into biological processes

84 **Awards:** Five companies receive awards for reinforced plastics uses

88 **Reports:** New energy sources to play a vital role in next 50 years

90 **Science Policy:** Budget cuts force Brookhaven lab to reduce its staff; starting salaries for engineering grads reach $30,000; Swedish energy policy relies on alternate and renewable sources

98 **New Developments:** Process utilizes coal without burning it; technique frees natural gas reservoirs; firm eyes fiber optics market

103 **Instruments:** On-board acoustic emission system hears flaws in aircraft; monitoring system leads welcome for *Columbia*; insulin infusion system builds on electronic advances

ARTICLES

106 **Light microscope sees materials of low reflectivity:** J.I. Siegel, Carl Zeiss Inc., using an "antiflex" system crisp images.

112 **Microcircuitry broadens microscope capabilities:** I.M. Stewart, McCrone; partial or complete control of microscopes and SEMs.

118 **Optical macroscope, SEM combined to improve analysis:** W. White Jr., and H.T. Tucker Jr., Franklin Research; SEM and optical systems.

124 **Small company—big contribution in 'inventivity':** J.J. Gilman, Amoco Research Center; company size and inventivity.

130 **Selecting graphics terminals for best long-term results:** Dean Bailey, Tektronix; common hardware and software of graphic terminals.

136 **Choosing programs for effective R&D:** M.D. Rosenau Jr., Rosenau Consulting Co.; you can minimize unimportant discoveries.

140 **Linear analyzer improves detection in radio-TLC tests:** H. Filthuth, Laboratorium Prof. Dr. Berthold; technique provides sensitivity.

147 **Trends in vacuum equipment in the '80s:** C.J. Mosbacher, executive editor, *IR&D*; materials handling in vacuum.

John J. Gilman
Gilman & Sutter
Amoco Research Center

Small company—big contribution in 'inventivity'

The ratio of patents produced to available funds gives a means for measuring a company's performance. Data indicate an inverse relation between company size and inventivity.

GENERAL OPINION suggests that smaller industrial corporations are more inventive than larger ones. But what is the evidence? And how strong is that evidence? To answer these questions, I have studied the rate at which patents are produced by various corporations that received the most U.S. patents during 1977.

As might be expected, more patents were granted to large corporations than to small ones—probably because they had more people working in their engineering and research operations. Therefore, the patenting rates were "normalized" by dividing them by the sales revenues of the corresponding corporations during the same year. I then plotted these normalized patenting rates against the annual sales revenues.

In the rest of this discussion, normalized patenting rates will be named "inventivities." This name has been chosen to suggest that this parameter is a subclass of productivity. It is the ratio of patents produced to sales revenues. In other words, it is the output that given input resources can produce.

Inspection of these comparative data indicates that the inventivities of firms with given sales revenue rates are nearly inversely proportional to the sales rates. Statistically, there is a strong inverse dependence in this log-log linear plot. Letting P = number of patents, and S = sales in billions of dollars, the correlation coefficient is 0.79—that is, relatively high correlation. The regression line is given by:

$$\ln(P/S) = 4.32 - 0.692 \times \ln(S)$$

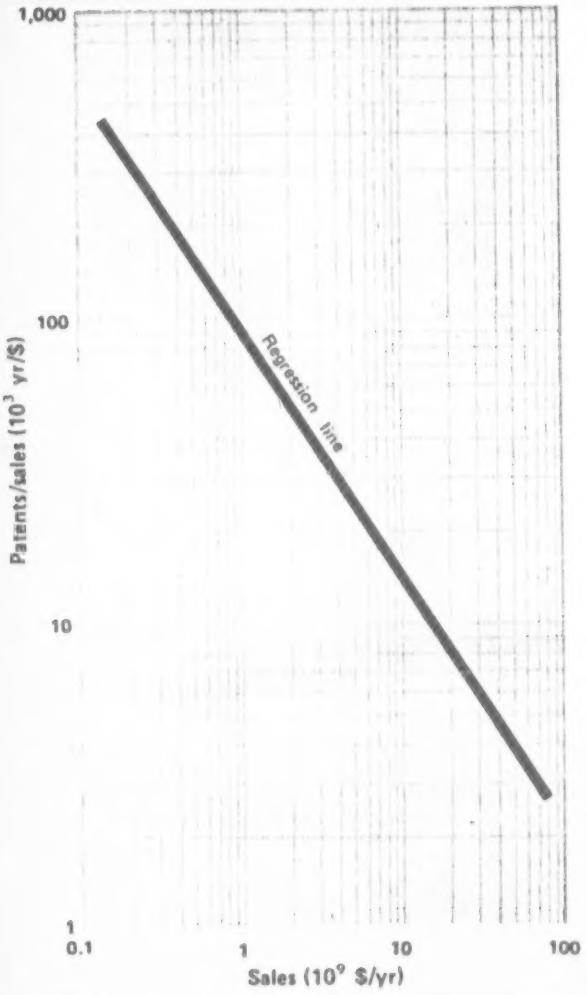
with a standard estimated error of 0.59. Since the slope coefficient is about 0.7 rather than 1.0, the dependence is not linearly inverse, but it is not far from it.

What does this correlation mean? It is doubtful that the independent variable is the inventivity. If this were the case, the results would suggest that deliberate suppression of inventions would tend to increase sales revenues by very large amounts. Adherents to conspiracy theories sometimes propose this, but it seems highly

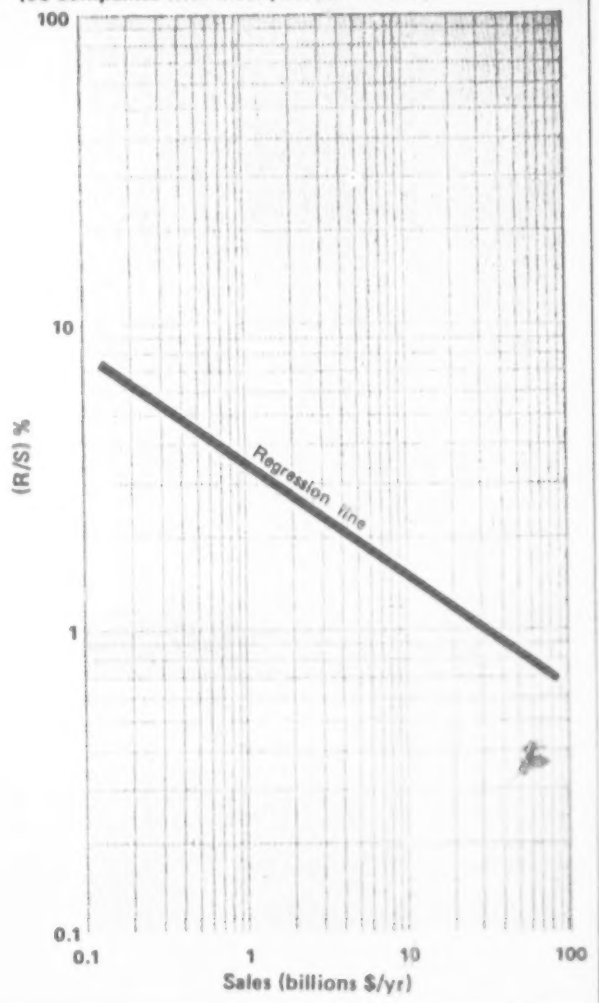
Comparison of inventivities for various companies

Company	$ (Billions)	Patents/ Sales	R/S (%)
Westinghouse	6.14	79	2.2
RCA	5.88	73	2.2
Caterpillar Tractor	5.85	57	3.8
Dow Chemical	6.23	48	3.3
Phillips Petroleum	6.26	43	0.8
Eastman Kodak	5.97	42	5.9
Rockwell International	5.86	29	1.7
Occidental Petroleum	6.01	18	0.5
Union Oil of California	5.87	10	0.3
Sun Oil	6.42	8	0.4
International Harvester	5.98	8	1.9

Correlation of inventivity with sales revenues
(95 companies with most patents in 1977)



Correlation of research expenditures with sales
(95 companies with most patents in 1977)



Comparison of companies with high and low inventivity

15 Highest			15 Lowest		
Company	P/S	R/S(%)	Company	P/S	R/S(%)
Xerox	97	5.3	General Motors	5	2.6
Motorola	116	5.9	Exxon	5	0.4
Upjohn	175	9.0	Texaco	7	0.2
Polaroid	112	8.4	Mobil Oil	6	–
Stouffer Chemical	94	2.6	Standard Oil (Calif)	7	0.4
AMP	172	9.2	Ford Motor	3	3.1
Bell & Howell	140	5.1	Standard Oil (Indiana)	8	0.6
Robertshaw Controls	251	2.3	U.S. Steel	8	0.5
Illinois Tool Works	195	1.6	Gulf Oil	4	0.4
Beckman Instruments	194	7.8	Atlantic Richfield	6	0.4
Nalco Chemical	105	3.3	Continental Oil	7	0.3
Eli Lilly	90	8.2	Sun Oil	8	0.4
Corning Glass	90	4.9	International Harvester	8	1.9
American Cyanamid	88	4.0	ITT	12	2.1
Merck	84	8.4	General Foods	11	0.1
Averages	134	5.7	Averages	7	1.0

unlikely for the large sample of companies.

Instead, the data may suggest that as an industrial corporation grows in its sales revenues, the production of inventions becomes less important in relation to other factors. The other factors may include financial strength, production skills, marketing tactics, raw materials supplies, and other such items.

One might be thinking that large corporations spend relatively less on invention activities than smaller ones do. This possibility was investigated by studying the normalized rates at which the same set of corporations spend their funds on research.

To evaluate the data, we plotted a log-log regression line for the relation of relative research expenditures to total sales. In this case, the correlation coefficient is only 0.4—about half as large as that of the data comparing inventivity to sales revenues. It may be concluded from this that normalized research spending depends more on the qualitative characteristics of a company than on its quantitative size as an operating unit.

One way to investigate how the qualitative characteristics of corporations affect their inventivities is to examine a set of firms lying within a narrow band of sales/year values. For example, the band that extends from $5.5 to $6.5 billion per year contains eleven companies.

These companies all have nearly the same sales revenues. On the other hand their inventivities vary by an order of magnitude from 8 to 79 patents/billion sales dollars. The relative amounts that they spend on research also varies by an order of magnitude. Yet inspection of the data shows only a weak correlation between their inventivities and research spending.

No significant qualitative pattern is evident. Still, the oil companies do tend to lie lower on the list than the equipment manufacturers.

A much stronger indication of the importance of qualitative factors is provided by considering the two sets of companies with the highest and lowest average inventivities, respectively. Those chosen are the 15 with the highest inventivities (P/S greater than 83), and the 15 with the lowest (P/S less than 13).

Inspection of the lists is consistent with the general reputations of the companies. Most of those in the highest inventivity list have reputations for doing substantial amounts of research, and for making product innovations based on research results. Those on the lowest inventivity list do not.

We note also that the companies on the highest list spend an average of 6% of their sales revenues on research and development, while those lowest on the list spend only 1% on average. In this latter case, even if the "oil companies" are eliminated, the R&D expenditures average about 2%.

The data presented here are for a single year. It seems unlikely that other years would yield dramatically different results. Yet it might be desirable to study similar data for additional years.

The cost of producing a patent is a parameter of interest. From the trends we have noted, it is clear that patents cost more in larger than in smaller firms.

For example, consider two imaginary firms that represent average behavior: one at the $10 billion sales level; the other at the $0.1 billion dollar level. The average value of R/S for the companies studied is 0.032. Therefore, from the regression line, the larger firm would spend (in 1977) about $2 million of R&D funds to produce a patent.

On the other hand, the smaller firm would spend only about $87,000—only about 4% as much as the larger firm. This might mean that much of what is spent for "R&D" in large firms is not directed toward making inventions. It also may mean that they do not spend the funds as efficiently as smaller firms.

In either case, a problem exists in the larger firms. There is either a problem of clarification so that management understanding can be improved, or a problem of spending the available resources to achieve more effective results.

If a majority of people agree that the national inventivity of the U.S. needs to be improved, then serious consideration should be given to the very strong influence of organizational size. What is true of commercial organizations very likely is also true of government and so-called non-profit organizations.

Thus we see that within existing organizations, means should be found for decentralizing authority to help create a sense of "smallness." The loss of fiscal efficiency that this might entail would be far less than the large potential gain in inventivity that should result.

It is important to keep in mind, of course, that while inventions play a crucial role in the process of innovation, the results presented here do not conclude that innovation correlates inversely with corporate size. Too many other factors play important roles in cause and effect.

Nevertheless, the very strong inverse dependence of inventivity on size should be taken into account when strategic plans are being made—both within corporations and external to them within society at large. □

THE AUTHOR

Dr. John J. Gilman is manager of corporate research at Standard Oil Co. of Indiana, Amoco Research Center, Naperville IL. A graduate of Columbia Univ., his interests include the direction and coordination of corporate research, as well as bringing new products to the marketplace. Dr. Gilman's R&D specialties include metallic glass materials, Alexandrite lasers, and new chemical processes. He has been active in both industrial and university R&D programs.